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DESIGN AND IMPLEMENT A MONITORING SYSTEM OF TRAFFIC SIGNAL USING MICROCONTROLLER DEVICES

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ABSTRACT

This project focused on designing traffic signal monitoring tools, based on ideas and concepts developed previously. Authors used the Arduino Nano module with ATmega328P as the microcontroller, which was chosen because it simplifies the scenario of traffic signal anomalies, short messages service (SMS) news content, and time settings. A microcontroller was used to process data from the interference detection result, and processing the SMS content, therefore, it is able to quickly inform the types of traffic signal disruptions. Based on result findings it is possible to utilize this development in building an integrated traffic signal monitoring system services, in the form of mobile applications in the near future.

Keywords: Monitoring system, Traffic signal, Microcontroller, Malfunctioning, Short message service

INTRODUCTION

Traffic signal infrastructure is responsible for assigning the right of way to vehicular and pedestrian passage at intersections. Meanwhile, its management and operations requires the proper design, location, operation and maintenance, to provide safe and efficient movements. A lot of mysteries surround its mechanism of action, although they are relatively simple as the installation comprises of traffic signal heads, detection and a controller, which is the ‘brains’ behind the equipment, containing the information required to force the lights through various sequences. These signals run under a variety of modes, dependent on location and time of day, which under fixed time operation, displays green to each approach for the same amount of time per cycle, regardless of the traffic conditions.

This may be adequate in heavily congested areas, while instances where a lightly trafficked side road is included within the sequence, the system becomes very wasteful, as no vehicles are waiting in some cycles, and the time could be better allocated to the busier approach. Vehicle actuation is one of the most common modes of operation, and as the name suggests, it takes into account demands on all approaches and also adjusts the green time accordingly. Furthermore, the requirements to actualize this mechanism are registered through the detection installed, either in the carriageway or above the signal heads, which the controller processes and further allocates the green time in the most appropriate way.

However, minimum and maximum periods are specified, and this cannot be violated, therefore, a vehicle passing a detector demands a certain phase and once that phase is green, any subsequently passing automobile, causes the phase to extend. This continues as such up to the point where either the traffic demand ceases and another approach gains green, or a conflicting demand causes the maximum timer to count down. Moreover, while vehicle actuation mode is more responsive than fixed time it also has the propensity of being inefficient in instances where long queues build up on conflicting approaches. The setting of maximum timers is then difficult due to changes in traffic patterns through junctions over time, which should therefore be regularly updated, in order to maintain effective operation. This is a labor intensive task for a local transportation authority, which is often not undertaken, thus leading to the signals becoming less effective over time.

As all electronic equipment, these devices are subject to breakdowns, malfunctions, and power outages, which could lead to safe intersections becoming dangerously congested and confusing, therefore resulting in needless accidents. However, a study on the city of Boston calculated that simply reconfiguring the timings of 60 intersections in one district of the city could save US$1.2 million per year, in terms of person-hours, safety, emissions, and energy costs [1]. In situations where malfunctioning occurs, the entity responsible for maintaining the signal may be held accountable, as regions and municipalities have a statutorily imposed duty, which ensure roads are safe for users. Furthermore, the Province of Ontario has set up certain minimum requirements for the maintenance of roadways, which include standards related to traffic signals, according to Regulation 239/02, which states the Minimum Maintenance Standards for Municipal Highways, under the Municipal Act. However, section 13 of the O.Reg 239/02 stipulates that in cases where a malfunctioning traffic control signal system occurs, the minimum guideline is to “deploy resources as soon as practicable after the awareness of the defect, in order to commence repairs or replacements” [2]. Meanwhile, most regions and municipalities have no statutory in this regards as Ontario, and due to the fact that most of the traffic signals are categorized as isolated intersections, the surveillance system is therefore highly dependent on road users report. Hence, response time needed is longer, especially during out of work hours.

This project focused on designing traffic signal monitoring tools, based on ideas and concepts developed from the research conducted by Sivarao et al. [3] and Anita Ahmad et al. [4], as well as self-diagnosis techniques, using the Reed-Solomon Codes by Tang and Wang [5]. Furthermore, a monitoring system with Proteus advancement tool, developed in Africa, was also used [6]. However, activities including designing concepts, materials selection, assembling tools, and traffic signal monitoring systems testing are rarely performed.

RESEARCH METHODOLOGY

The product was designed based on electronic circuit plan, where all blocks were arranged on the project board and tested individually, and also a combination on printed circuit board (PCB) was conducted, at periods of proper function. This study used the Arduino Nano module with ATmega328P as the microcontroller, which was chosen because it simplifies the scenario of traffic signal anomalies, short messages service (SMS) news content, and time settings.

This also facilitates programming, possesses a memory capacity that is capable of accommodating program scripts, it is affordable, readily available, and is relatively small in size.

However, programming was carried out using the built-in Arduino IDE open-source software, and the general description of electronic circuit design is seen in Fig. 1 as developed previously [7, 8, 9].

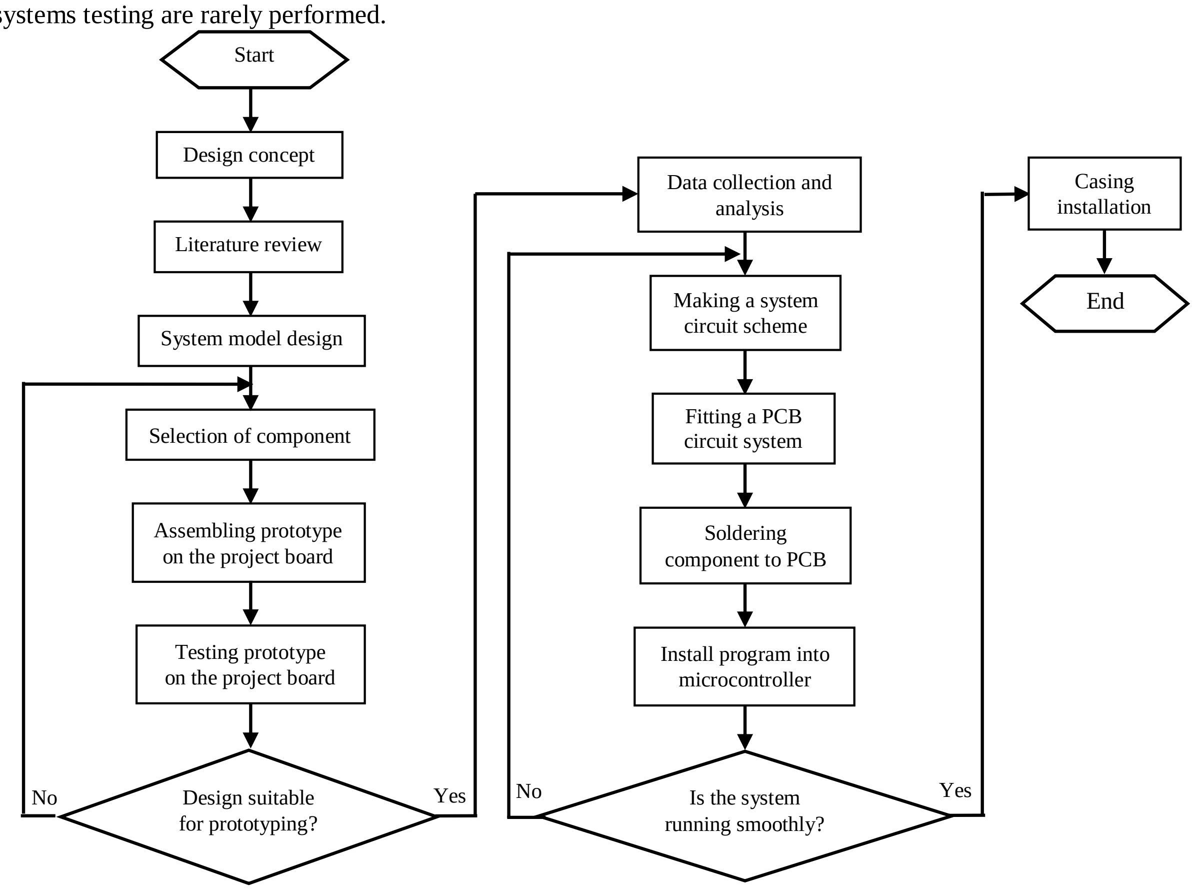

Fig. 1 Design circuit flow chart

RESULT AND DISCUSSION

Each traffic signal display is equipped with a form of light sensor, positioned in a way, in order to detect beams from the traffic signal. This is then processed by the logic gate and microcontroller to be diagnosed, based on the rational state, guard time and verification of the programming anomaly scenario. Furthermore, the microcontroller recognizes the anomaly and immediately turns all traffic signal display (red, yellow and green) off. Meanwhile, during the termination process, the microcontroller instructs the A6 GSM module to dispatch an SMS, at certain time intervals, according to the program (e.g., once every hour). Therefore, the emergency light flashes periodically, serving as a visual marker, which indicates that the signal is under repair. Hence, mobile or smartphones can be used as an SMS receiver by entering the recipient's number from the traffic signal in the microcontroller program.

Switching mode power supply (SMPS) with DC 12V 10A voltage was used as the main source. This voltage was chosen to supply the relay and a series of LED lights on the traffic display and emergency flash. In addition, step-down DC to DC buck converter was also applied by reducing the DC 12 Volt voltage from SMPS to DC 5V 3A, which was further used to supply logical state, guard time, data latch, reflected light sensor, GSM A6 module, and the microcontroller as shown in Fig. 2.

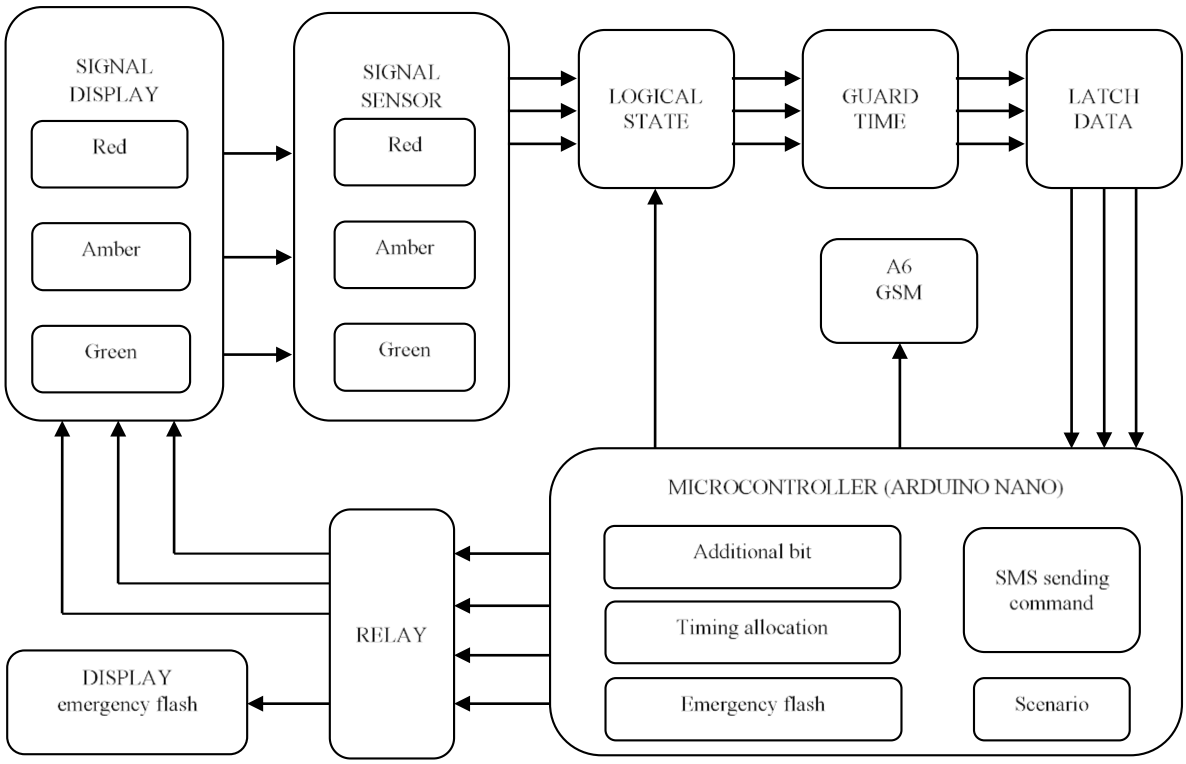

Fig. 2 Devices diagram block

Referring to Fig. 2, a design of electronic series consists of some blocks:

1. The traffic signal display block consists of the combination of a series of light emitted diode (LED) illuminations (red, amber and green), and placed between them are three light dependent resistor sensors (LDRs), used to detect reflections produced by LEDs and other reflectors.

2. The emergency flash display block consists of a combination of LED beams, functioning as visual markers, and the main traffic signal, during the repair process.

3. Reflection sensor block. The readings of each LDR (red, amber, and green) are entered into three voltage comparator circuits. Therefore, if it obtains reflected light, the sensor produces a LOW logic, and on the contrary, a HIGH logic is emitted in the absence of reflected light.

4. The logical state block is an electronic path, which uses an integrated circuit (IC) type CD4028 (BCD to decimal decoder), designed to identify different bits of each sequence of statement traffic signals, in cases of anomaly. Furthermore, the input pin of this IC is a 4-bit binary number (from 0000 to 1111), while the output pin is represented by 10 digits (Y0 to Y9). The following are some identity bits designed for each traffic signal anomaly statement:

4.1. the red display is given the 0101-bit, characterized by pin Y5.

4.2. the amber demonstration specifies the 0011-bit, represented by pin Y3.

4.3. the green exhibition is allotted the 0111-bit, denoted by pin Y7.

5. Guard time block: Anomalous data Y5, Y3, and Y7 cannot be considered valid when in the guard time series, which was allotted a time period of 1 second in this study. For example, if Y5 sends an

under-1 second-anomalous signal, it is not considered an anomaly and vice versa.

6. Latch data block: After the validity of the anomaly signal has been considered, the block is then locked (latch). This is further processed by the microcontroller, at the end of a cycle of traffic signal.

7. Microcontroller block: This is divided into five sub-blocks with their respective functions, including:

7.1. timing traffic signal functions as a time allocator per cycle.

7.2. Provision of additional bit function for CD4028 IC input (logical statement block), in determining bit during an anomaly.

7.3. Anomaly data verification scenario, through the process of matching results of processing data latch blocks with anomalous scenarios, which have been programmed in the microcontroller.

7.4. SMS sending command, when a change in the traffic signal anomaly was considered a malfunction (through the verification process) to be forwarded as news to the A6 GSM module block.

7.5. emergency flash: This sub-block works by flashing, depicting a sign that the main traffic signal is under maintenance.

8. The GSM block A6 module works by sending SMS on the processing results, from the microcontroller to the operator. This occurs because the unit has been recognized by the Arduino library, therefore, it is easily programmed in the IDE, with the AT command instruction set.

9. Relay block is a series, consisting of 4 types of transmissions, while the ULN2803A IC and opto-coupler turns ON or OFF the traffic signal display and emergency flash. These conditions for the four types of relay, follow the order of the microcontroller sub-block timing functions.

The traffic signal cycle in this study followed the sequence as shown in Fig 3.

1. Red OFF, Amber ON, Green OFF;
2. Red ON, Amber OFF, Green OFF;
3. Red ON, Amber ON, Green OFF;
4. Red OFF, Amber OFF, Green ON;
5. The second cycle (restarts from Red OFF, Amber ON and Green OFF).

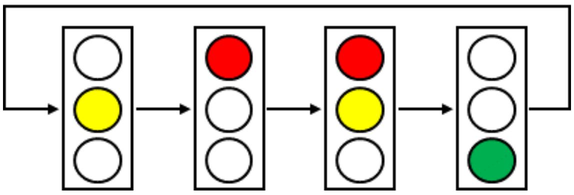

Fig. 3 Traffic signal cycle

Hence, the implementation of a monitoring system completely as combined work of Fig. 1 and Fig. 2 respectively, shown in the Fig. 4 below.

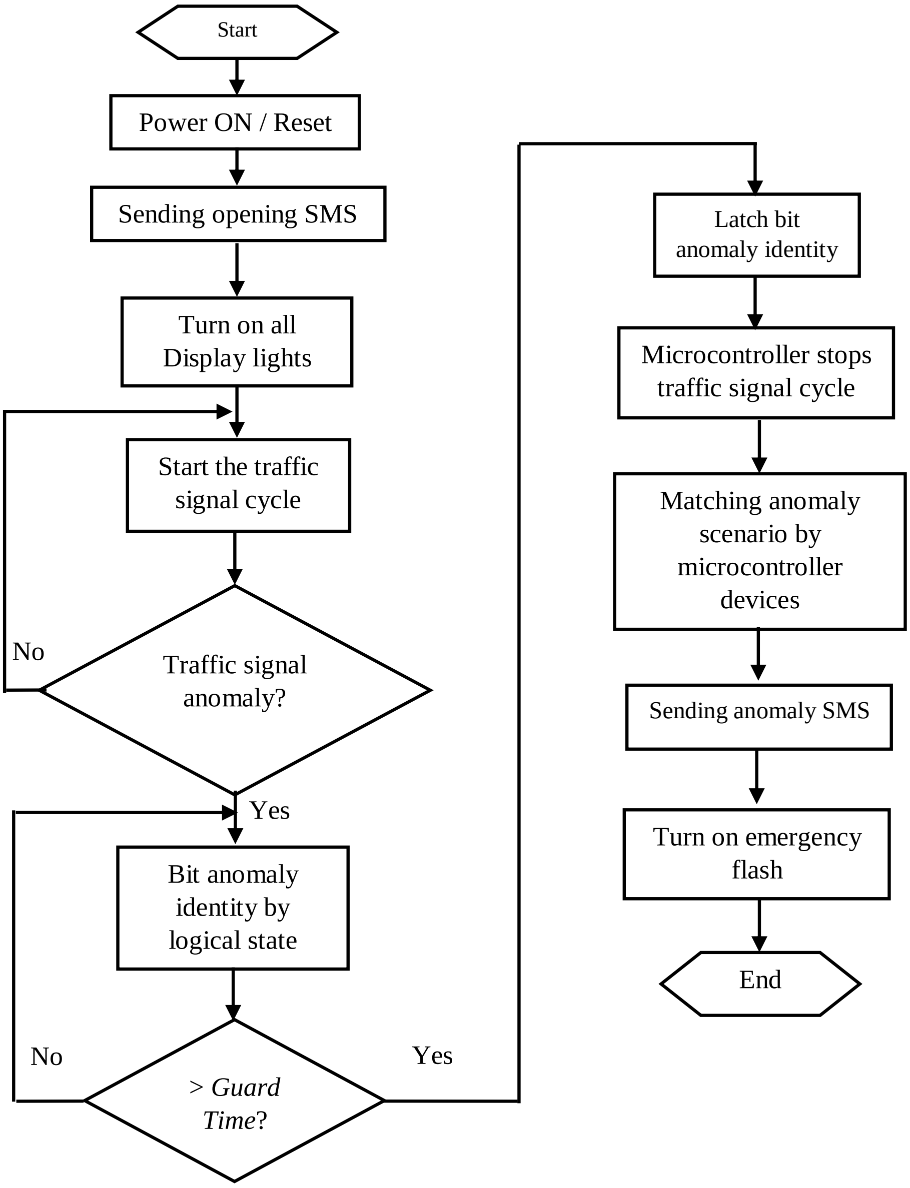

Fig. 4 Flow chart of signal monitoring system

CONCLUSION

This research highlights the ability to autonomously diagnose traffic signal device systems, especially in its work function, with the intent to detect interference on the device, and provide report via short message service (SMS) to a monitoring unit. Furthermore, this can be placed in any area covered by the Global System for Mobile Communication (GSM) wireless communication service. Meanwhile, a microcontroller was used to process data from the interference detection result, and processing the SMS content, therefore, it is able to quickly inform the types of traffic signal disruptions. Hence, it is possible to utilize this development in building an integrated traffic signal monitoring system services, in the form of mobile applications.

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